Telesonar Network for the FRONT Undersea Sensor System

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LONG-TERM GOAL

Modern electronics, digital communication theory, and acoustic energy propagation will provide the basis for implementing sophisticated wireless undersea sensor networks.

OBJECTIVE

This project advances communications technology in support of the scientific objectives of the NOPP Front-Resolving Observational Network with Telemetry (FRONT) effort. We apply undersea acoustic communication (telesonar) capabilities now being developed for deployable autonomous distributed surveillance and other Naval missions to a remote field of moored oceanographic sensors at a complex site on the North American continental shelf.

APPROACH

Spatial sampling of ocean fronts on the inner continental shelf (20-60 m deep) requires undersea sensor distribution over roughly a 20-km by 20-km geographic area. Sparse sensor placement at the FRONT observatory, as charted in Figure 1, poses a technological challenge for reliable delivery of data to shore and sensor control from shore. Vulnerability of cables to commercial trawling precludes the use of a wired sensor network. Vulnerability of surface buoys to weather, rough seas, and pilfering discourages reliance on radio telemetry from individual sensor nodes to shore or to space satellite.

An undersea acoustic network is a cost-effective alternative enabled by recent and ongoing technology developments for distributed littoral surveillance. Such a distributed network involves multiple horizontal links between sensor nodes, relay nodes, and gateway nodes, as depicted in Figure 2. With ONR sponsorship, SSC SD is advancing telesonar digital communications[1] for use in adverse undersea acoustic channels[2] such as those existing between sensor nodes at the FRONT site. Telesonar signaling is inherently channel tolerant,[3] and ongoing developments will produce adaptive modems that probe the channel, estimate the prevailing propagation parameters, and optimize the modulation for energy efficiency.[4] We are developing telesonar technology to support deployable autonomous distributed sensor networks having topologies, throughput requirements, and battery constraints similar to those of FRONT. Thus, pertinent multi-access interference issues and resource-optimization issues are being addressed.[5] In addition, radio gateway nodes are being used to link the undersea network to terrestrial networks or directly to the shore-based user.

Telesonar networks support packetized data telemetry from the network as well as remote control

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and interrogation of specific sensor nodes from ship and shore sites, or via the internet. The operational concept is known as "Seaweb," and SSC SD is committed to executing a series of progressive Seaweb experiments on an annual basis. Seaweb'98 was the first such installation, and it successfully delivered asynchronous digital data from various commercial oceanographic sensors via multiple telesonar nodes. Seaweb'99, Seaweb2000, and Seaweb2001 will demonstrate increasingly sophisticated and increasingly robust telesonar networks. With the objective of self-configuring, scaleable networks for undersea warfare applications, we are performing basic research in acoustic propagation and coordinating the development of signaling theory, modems, directional transducers, gateway concepts, handshake protocols, network designs, and multi-user access strategies.

SSC SD is working toward a long-range goal of networking dissimilar, arbitrarily placed, stationary and mobile, undersea nodes using auto-configuration, self-optimization, self-healing, and environmental adaptation. The FRONT network is much less demanding because it can be pre-planned and remotely configured, as Figure 3 suggests. Hence the FRONT application is well matched to the telesonar state of the art expected to exist during the three-year term of the project.

We will carefully place the FRONT sensor nodes, repeater nodes, and gateway nodes to provide maximum flexibility and redundancy in the network. Multiple routes will exist between sensor nodes and gateway nodes, as shown in Figure 4, permitting the shore-based network administrator to reconfigure the network as needed. A limited number of node failures can also be tolerated through remote network reconfiguration. Likewise, we can assimilate new node additions at any time. Such a network philosophy provides maximum utility of the FRONT observatory while simultaneously providing the Navy an appropriate case study for Seaweb technology development. Telesonar and Seaweb technology will advance appreciably during the three-year FRONT project because of hardware and software developments now underway. These technology improvements will be introduced to the FRONT network to incrementally improve quality of service. Meanwhile, the FRONT application lets SSC SD relate network performance to a demanding time-variant ocean environment expected to be well-characterized by the scientific component of the FRONT project.

Our FRONT network design will focus on optimizing quality of service and energy efficiency for a given stationary deployment in a known environment. We are analyzing the site for acoustic propagation and optimized node placement, including use of relay nodes for improved communication links, redundancy, and data relay to near-shore gateway nodes. We are working with our NOPP partners to define and compress communication packet content. Data packets of 1 to 4 kbits are anticipated. A multi-user access strategy designed for FRONT is being extensively simulated and implemented during the August SeaWeb'99 in Buzzards Bay.

SSC SD is providing second-generation telesonar modems on loan for installation in FRONT-1. A cellular telephone to be installed at a Coast Guard buoy near Montauk Point, NY will serve as the only gateway. The third-generation telesonar modem now being developed under SSC SD contract will become commercially available from Benthos in early 2000. FRONT-2 will use the new modems, and include additional sensor nodes for up to three months of testing. These two engineering deployments will provide performance measures under extreme environmental conditions.

NOPP partner UConn will procure twenty modems and will install two gateway nodes for dedicated use during years 2 and 3 of the project. UConn will provide this equipment as Seaweb2000 assets for thorough testing and evaluation, including full integration of FRONT sensors. SeaWeb2000 will introduce major advances in telesonar network protocols, including CDMA node addressing. Following SeaWeb2000, the FRONT-3 deployment will last six to ten months.

After the NOPP partners analyze observed frontal phenomena, we will redesign the sensor network to examine specific features or finer scales or to include additional nodes. These changes will prompt alterations in the network topology, and this evolution will offer us an opportunity to upgrade the modems and network protocols with the latest evolution of technology. We will again test the network and FRONT sensors during SeaWeb2001, and the FRONT-4 installation will ensue, with ocean observation lasting up to ten months.

WORK COMPLETED

This three-year project began in fourth quarter FY99. We have planned a series of at-sea engineering experiments in association with FRONT partners UConn and Benthos. Prior to the FRONT-1 installation, Seaweb'99 and ForeFRONT-1 will test and refine communications technology and ensure compatibility with oceanographic sensors and ashore user interfaces. Likewise, ForeFRONT-2 will precede FRONT-2, Seaweb2000 will precede FRONT-3, and Seaweb2001 will precede FRONT-4.

RESULTS

Seaweb'99 included fifteen telesonar nodes deployed in the shallow waters of Buzzards Bay. During Seaweb'99, we found issues related to interfacing RDI ADCP sensors with ATM-875 telesonar modems. In preparation for ForeFRONT-1, these issues were resolved.

During Seaweb'99, the telesonar network was accessed using a network gateway installed on a USCG caisson. Below the caisson a stock telesonar modem acted as a Seaweb network node. The modem was interfaced to a Bell Atlantic cellular telephone mounted on the caisson above the waterline. This provided a TCP/IP link to any authorized internet server. In this case, the link was tested at the Seaweb command center manned by project personnel.

During Seaweb'99, we implemented a rudimentary command-center user interface using a National Instruments LabView application installed on a laptop PC running Windows NT. We accessed the telesonar network using both the TCP/IP gateway and a point-to-point packet radio link to a second gateway node. Seaweb'99 demonstrated bidirectional communications, with remote control commands to the Seaweb network and data delivery from the Seaweb network.

During Seaweb'99, we remotely reconfigured the network topology, performed node-to-node ranging, and exercised node-to-node data packet transfer.

Seaweb'99 was a successful start in a series of incrementally evolving technology implementations supporting the FRONT scientific obectives.

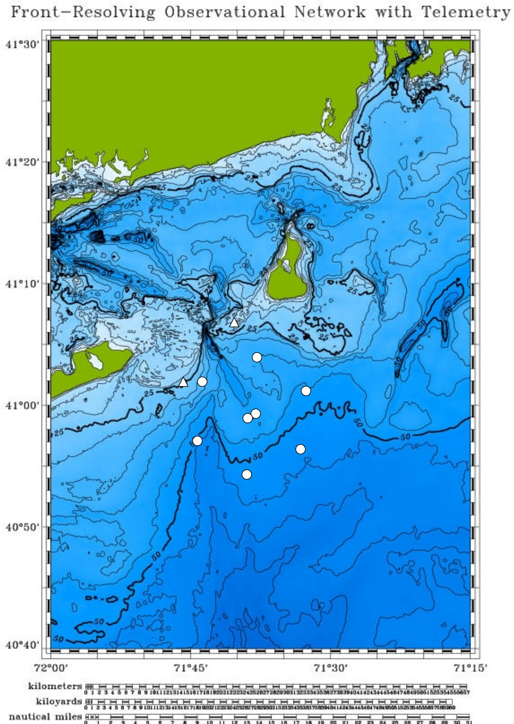

Figure 1. Eight sensor nodes and two gateway nodes in 20- to 60-m continental shelf water.

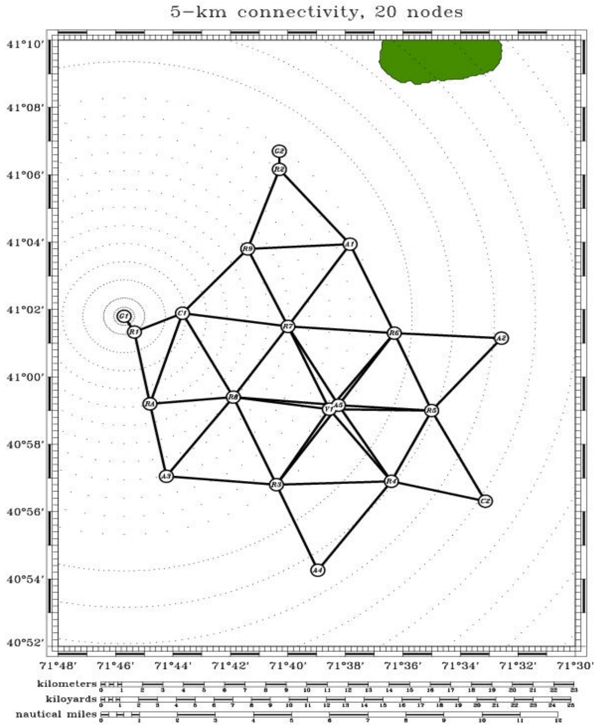

Figure 2. Relay nodes will reduce spacing from 9 km to 5 km.

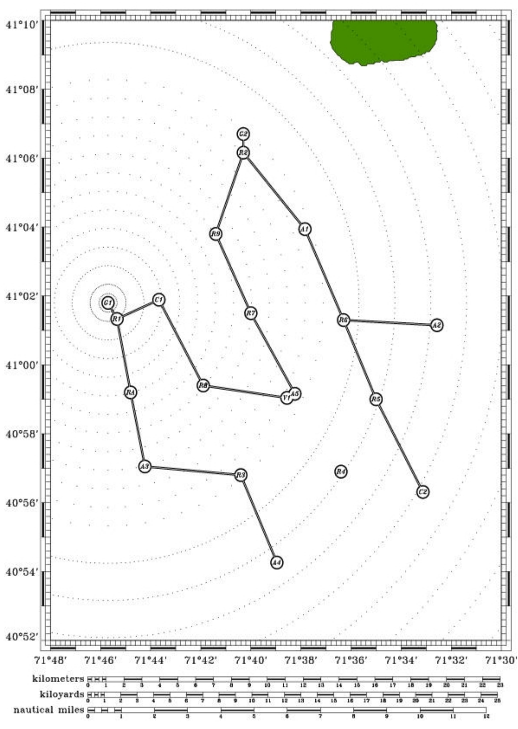

Figure 3. Binary tree routing topologies will minimize multi-access contention.

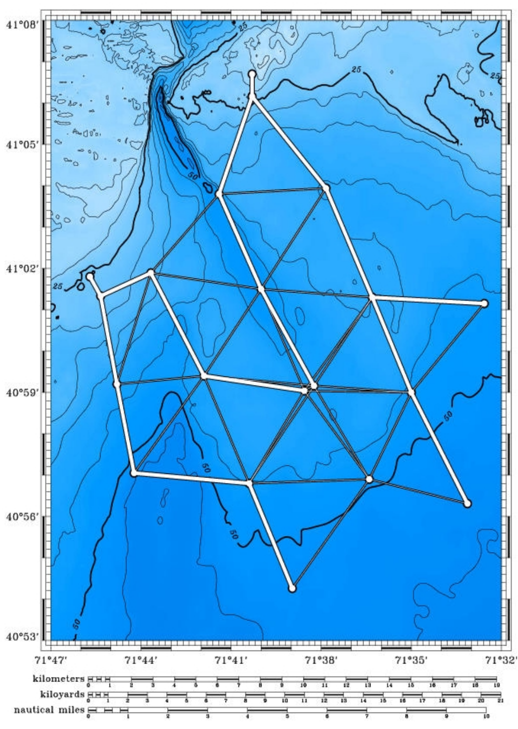

Figure 4. Primary and secondary links will be configurable by ashore network administrator.

IMPACT / APPLICATIONS

FRONT provides an immediate application for telesonar networks, thereby accelerating incremental development of Seaweb technology.

FRONT sensor networks may be deployed in other ocean environments.

TRANSITIONS

FRONT furthers the concept of the Seaweb undersea wireless internet for overarching command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR), including network-centric operations in the undersea battlespace.

Telesonar technology enables deployable autonomous distributed systems (DADS) and other undersea-warfare applications. Because certain DADS technologies are not yet mature enough to permit realization of the DADS concept, FRONT presents an unclassified application with similar operating environment, node spacing, and data rates. FRONT deployments will include planned outages during which surveillance applications and other undersea applications will be explored using the communications infrastructure.

The FRONT installations permit prolonged observation of the relationship between network performance and independently observed environmental influences. A by-product of the FRONT partnership is the availability of time-variant oceanographic data--measured and predicted--for validating and refining numerical telesonar channel models.

RELATED PROJECTS

This is one of several FRONT projects coordinated by UConn and funded by NOPP. This project uses ONR 321SS telesonar testbeds, SSC SD ILIR physics-based models, and ONR 321SS ocean experiments.

This project is performed as a component of the SSC SD Seaweb S&T Capabilities Initiative. Seaweb is a concept for telesonar network infrastructure linking autonomous undersea assets and including gateways to manned command centers submerged, afloat, aloft, and ashore. SSC SD has established the Seaweb Initiative as an internally funded umbrella program advancing telesonar C^4ISR. The Seaweb Initiative coordinates the following telesonar research & development efforts:

SSC SD ILIR Telesonar Channels Project (6.1) seeks a theoretical and experimental understanding of telesonar propagation physics, including such impairments as multipath, scattering, variability, fading, attenuation, and noise.

ONR 321SS Telesonar Link Protocols Project (6.2) develops prototype telesonar technology in the form of energy-efficient, affordable, DSP-based modems using channel-tolerant signaling for link establishment, acoustic probes for in situ channel estimation, and adaptive modulation for optimized channel capacity.

ONR 322OM Telesonar Modem Performance Project (6.2) conducts experiments for assessing the relative performance of multiple telesonar signaling techniques in relation to prevailing channel conditions.

ONR 321SI DADS Network Task (6.2) applies telesonar technology for enabling the Deployable Autonomous Distributed System, a concept for wide-area undersea surveillance particularly suited for shallow-water ASW.

PD 18E Sublink Task (6.3) integrates telesonar technology into submarine UQC-2 underwater telephone systems for digital data and digital voice links with other platforms and off-board systems. ONR 321 Telesonar Surveillance Applications Project (6.3) advances communications infrastructure for Future Naval Capabilities in littoral ASW.

NOPP Front-Resolving Ocean Network with Telemetry Project relies on telesonar technology for networking oceanographic sensors and delivering data to a gateway buoy linked by cellular telephone to the terrestrial internet as a component of the National Oceanographic Partnership Program.

ONR 36 SBIR Program entrusts technical oversight to SSC SD for Small-Business Innovative Research industrial contracts concerning telesonar modems (SBIR topic N93-170), telesonar networks (N97-106), and telesonar directional transducers (N99-011).

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